Evolution of radiative properties over tropical mesoscale convective system life cycle

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ISRO-CNES megha-tropiques

Earth Radiation Budget workshop

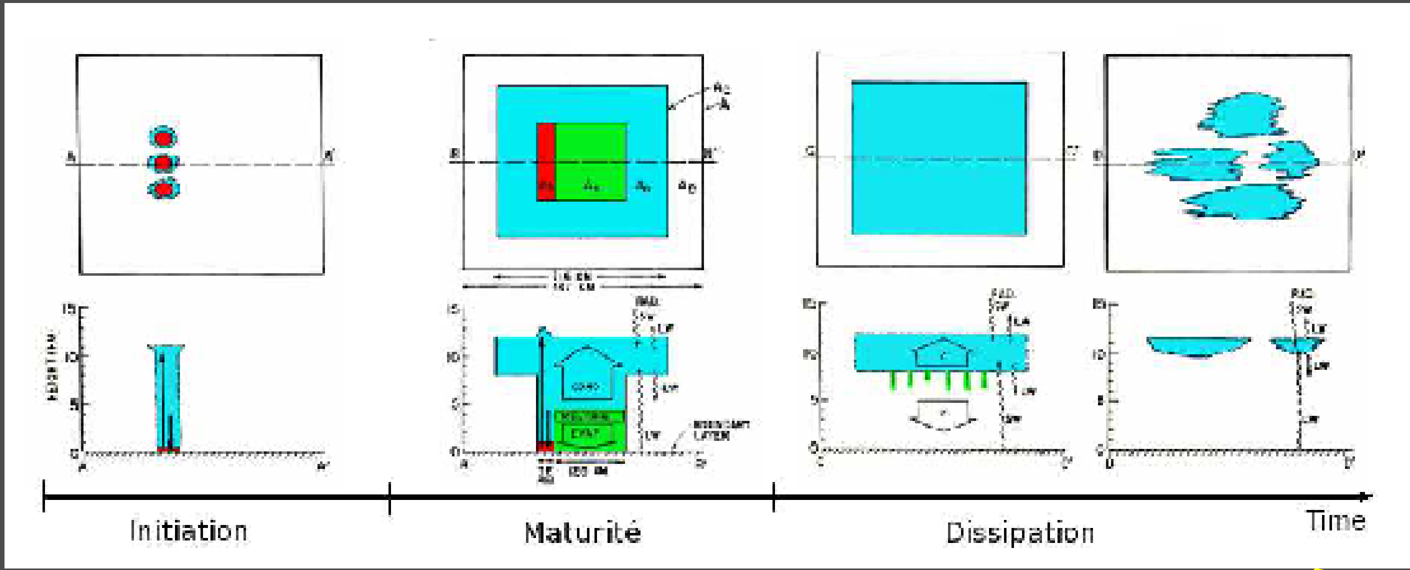
18-21 october 2016

cnrs dépasser les frontières

METEO FRANCE Toujours un temps d'avance

MCS life cycle

Strong rain + latent heat release



Houze, 1982

The life time of MCS anvil clouds + its size make its radiative impact non negligible.

How the microphysical changes over the life cycle affect the radiative properties ? Is it different from one geographical area to the other ?

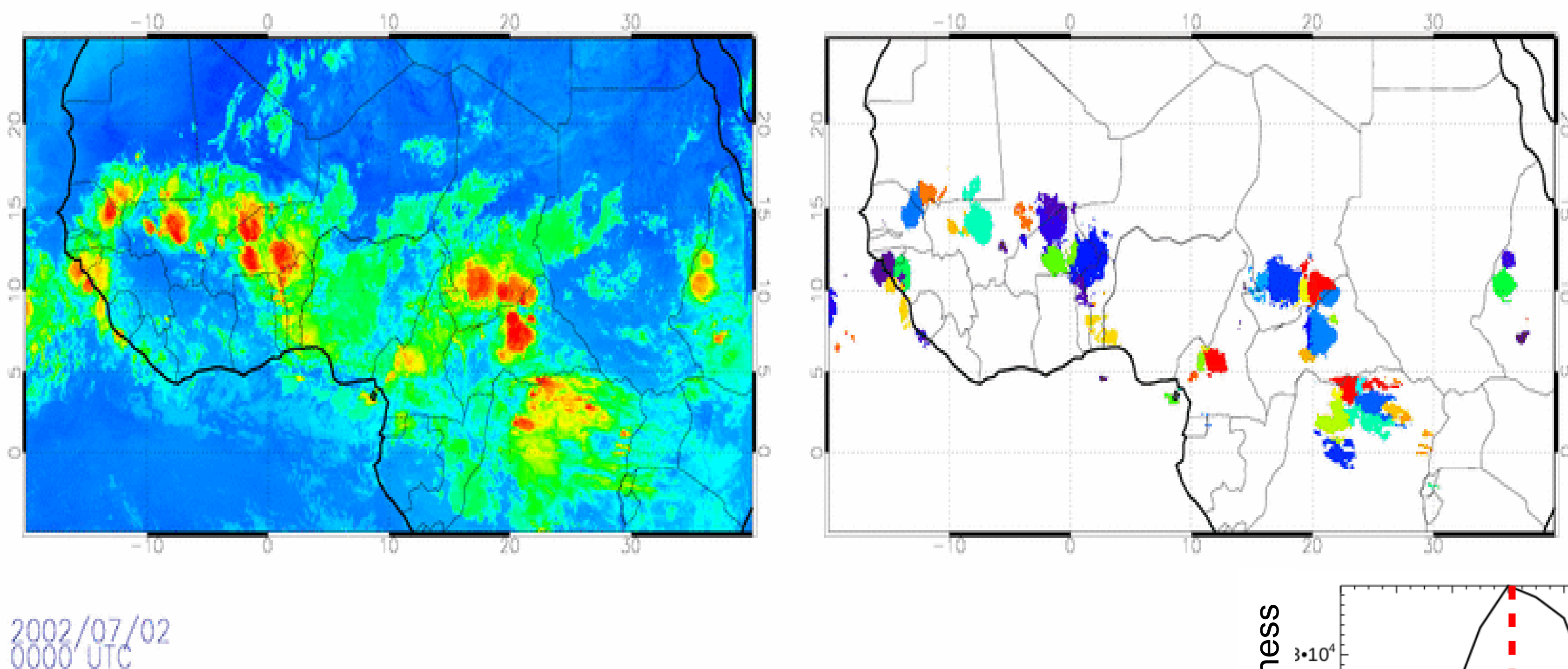
Documentation of the evolution of the associated latent and radiative heating profiles
Improve the representation of cloud detrained from convection within GCMs

Satellites (in particular orbiting) are powerfull tools for documenting the MCS physical properties all around the Tropics (continent and ocean)
But need to include the temporal dimension !

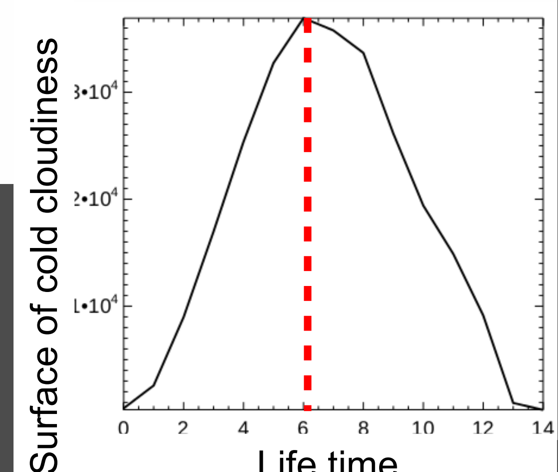
MCS evolution in geostationnary images – add the temporal dim.

Identifying MCSs in IR satellite images and tracked them along time : TOOCAN algorithm (*Fiolleau and Roca, IEEE, 2013*)

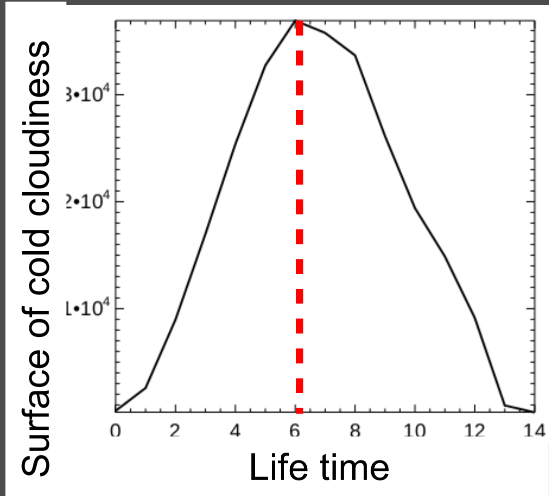
- TOOCAN defined the MCS enveloppe at the 235K level = cold cloud shield associated to MCS
- Tb < 235K belong to a cv system



For each MCS : life duration, maximum size, time this maximum is reached, position, trajectory ...
Avoid traditionnal splitting & merging artefact



Normalisation of the cold cloud shield life cycle

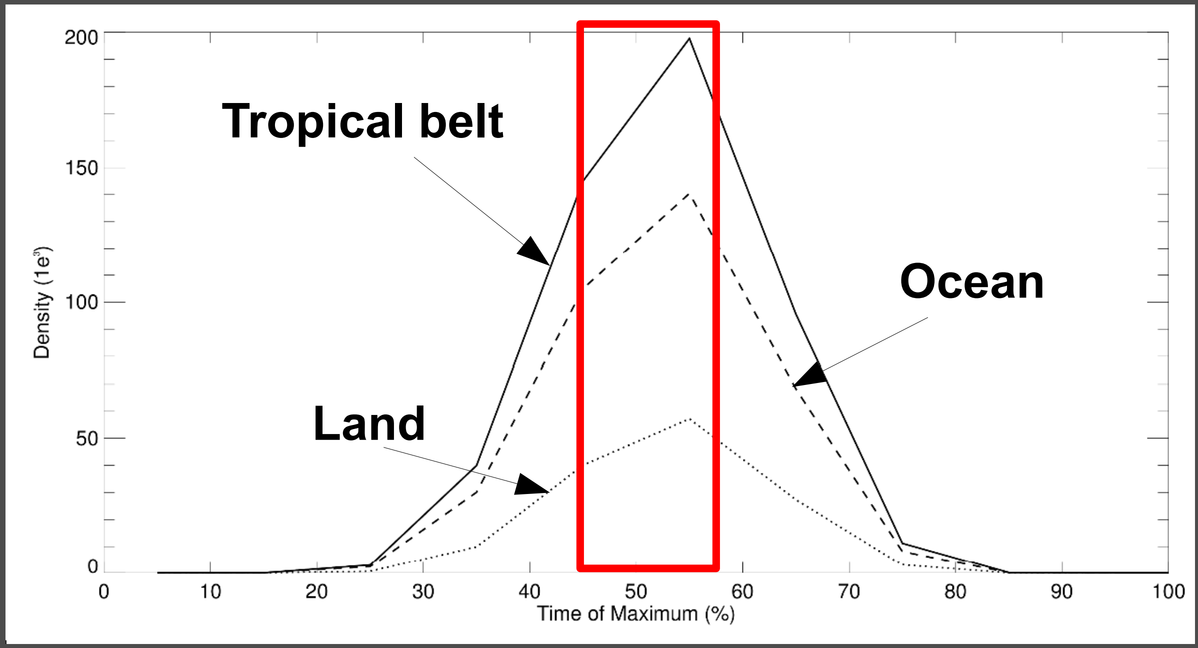


The life time is divided in 10 steps => life stage will be between 0 and 1

- Life time must be longer than 5 hours (10 images)
- The cloud shield must only have one phase of growth and decay

	Contribution to the total occurrence (%)			Contribution to the total cold cloudiness (%)		
	All	Land	Sea	All	Land	Sea
Number	884,063	246,080	637,983			
Life time < 5h	27	32	26	2,5	3	2
Life time > 5h simple	60	58	60	84	85	84
Life time > 5h complex	13	10	13	13,5	11	14

Main contribution to cold cloudiness



Maximum extend of the cold cloud shield is reached at the middle of the life cycle
=> symmetric life cycle
=> larger systems are the longer
=> composite can be built in a normalised framework

Roca et al. (in rev. JClim 2016)

Evolution of processes along MCS life : orbiting satellites TOOCAN + A-Train

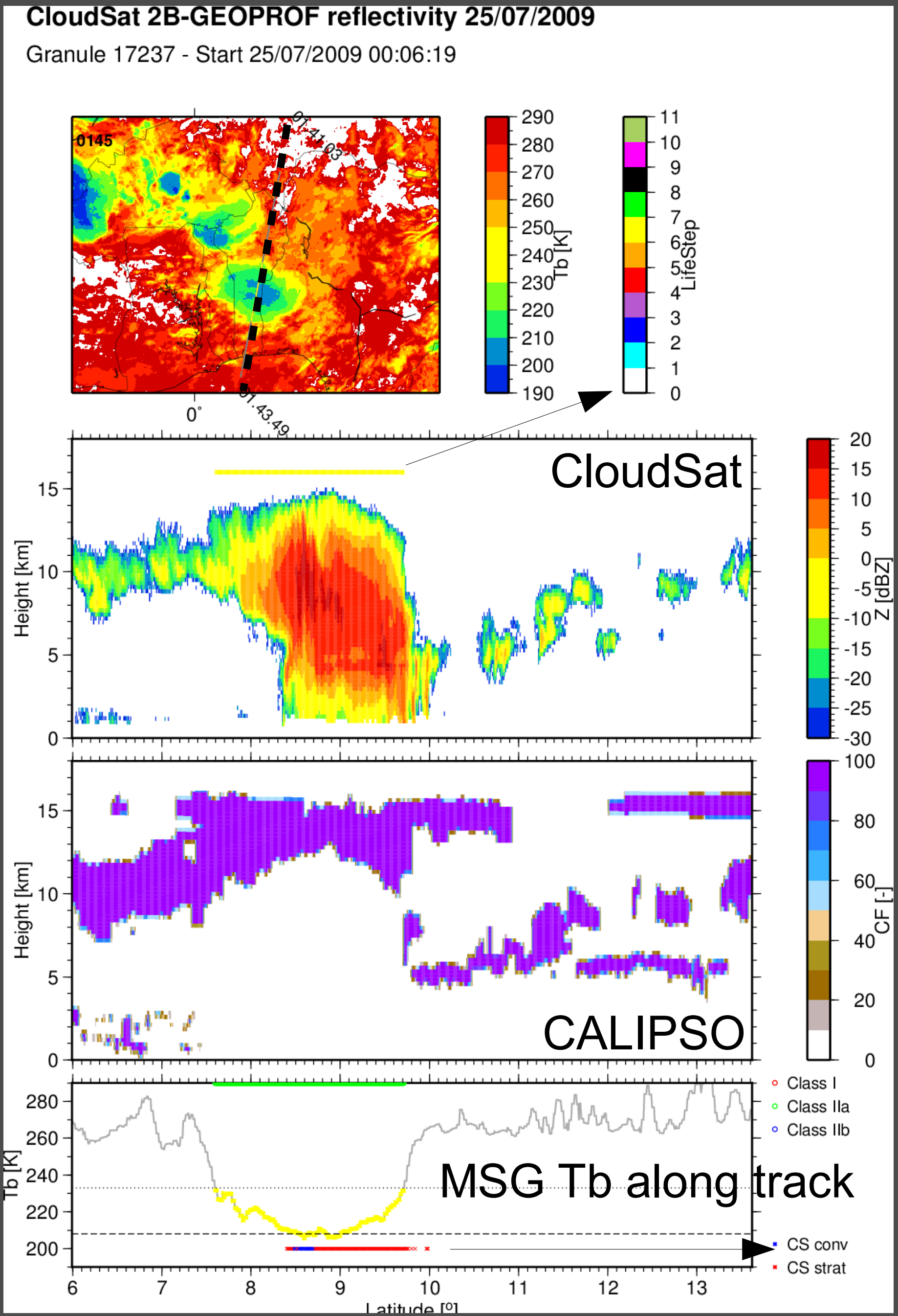
Intersection of TOOCAN trajectories with A-Train tracks

TOOCAN
MCS life step

TRMM
Conv./strat. Flag
2A25

Macrophysics
Scanning capability

3 MCS sub-regions
Processes are different between convective/stratiform /cirriform regions of a MCS
10 life steps



A-Train

Conv./strat. Flag
CloudSat (2C-PRECIP-COLUMN)

Macrophysics
CloudSat + CALIPSO (2B-GEOPROF-LIDAR)

Microphysics
CloudSat (2B-GEOPROF)

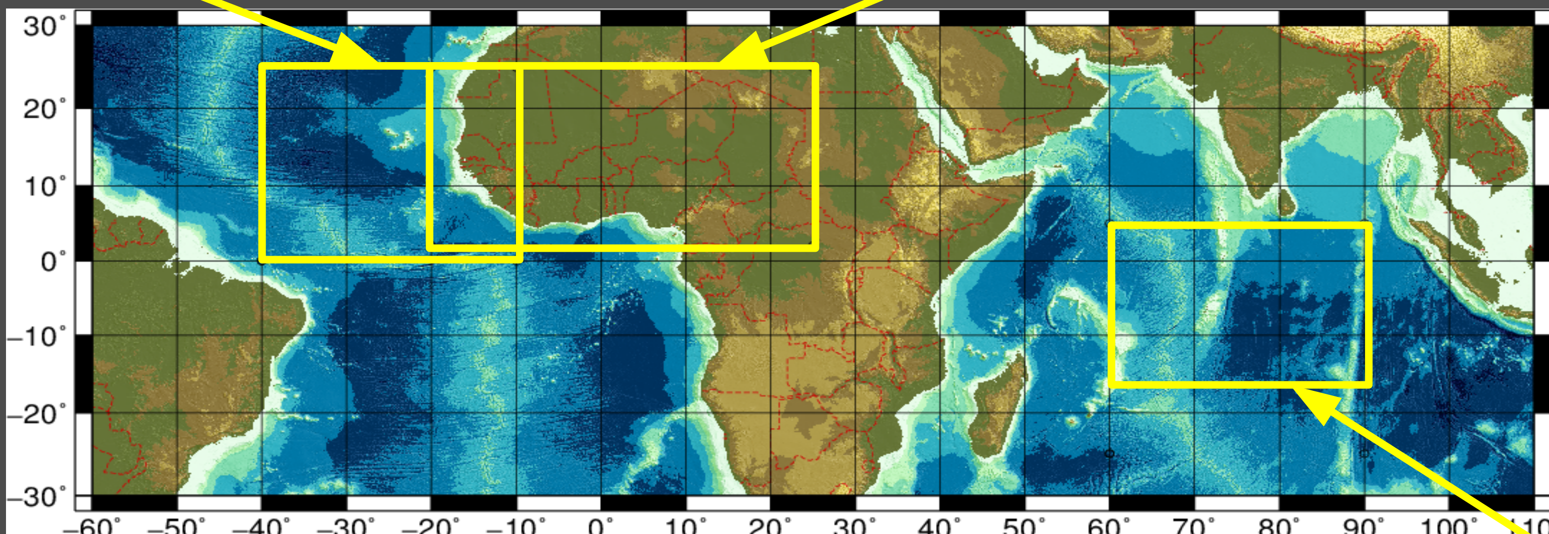
TOA/BOA radiative fluxes
CloudSat-CALIPSO (2B-FLXHR-LIDAR)
CERES-CloudSat-CALIPSO-MODIS (CERES-C3M)

Radiative heating rate profile
CloudSat-CALIPSO (2B-FLXHR-LIDAR)

Three constrasted tropical regions :

Atlantic ocean – ATL
Ocean only - summer
June to september
2006-2010

West Africa – AF
Land only - summer
June to september
2006-2010



Open Indian Ocean – OIO
winter
November to February
2006-2011

CloudSat CPR
Nb of sampled systems/Nb of profile

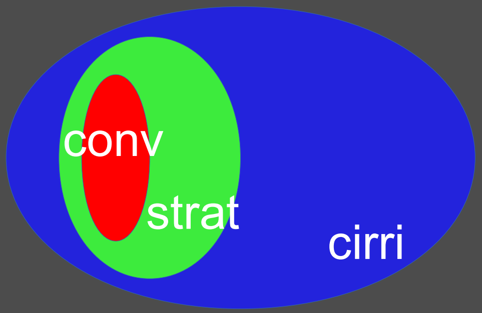
	AF			ATL			OIO		
	Conv	Strat	Cirri	Conv	Strat	Cirri	Conv	Strat	Cirri
1	76/572	102/1259	127/2017	**17/84**	35/417	44/703	72/402	125/1989	180/2593
2	132/1166	168/3247	243/6938	66/582	108/2106	107/2336	144/974	243/4821	301/7836
3	165/2296	222/7460	259/10874	82/730	132/3296	141/3883	250/1754	412/12484	499/19373
4	140/1934	183/10329	233/12853	123/1163	177/7243	185/7093	320/2880	524/22113	641/24742
5	133/1756	173/12763	236/15156	99/847	156/7751	1828/8426	261/2009	507/21720	644/31906
6	100/1271	177/8537	244/15452	98/660	180/7411	223/9836	252/1670	546/24104	753/37457
7	85/627	167/9979	258/14361	85/609	159/6720	208/9236	179/1006	433/17818	655/33193
8	46/207	123/5492	213/9034	35/231	95/3508	150/4767	95/426	282/7979	499/20209
9	28/85	78/2395	159/5072	**16/55**	41/739	85/2311	33/72	118/1980	298/8833
10	**3/8**	**15/165**	37/433	**0/0**	**3/21**	21/235	**4/6**	**19/197**	86/1555

Because of their size at a given life stage
- Some MCS sub-regions are not enough sampled (lack of representativity)
- Without the distinction in life stage it is mainly the middle of the life cycle which is sampled (oversampling)

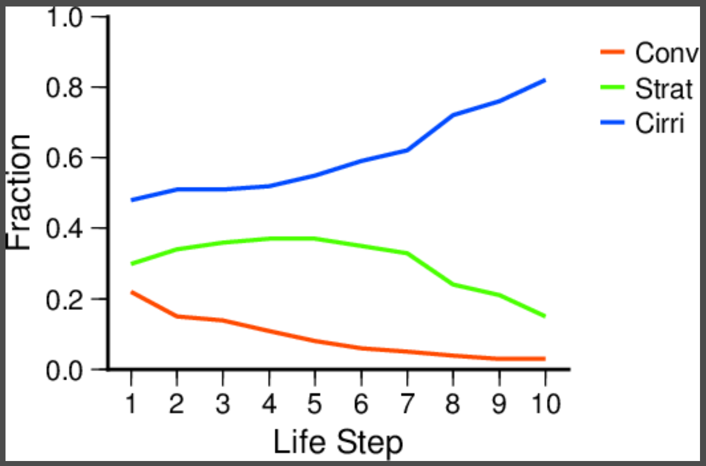
Relative evolution of each sub-region at the scale of the MCS :

TOOCAN MCS trajectories and TRMM-PR intersections are sought

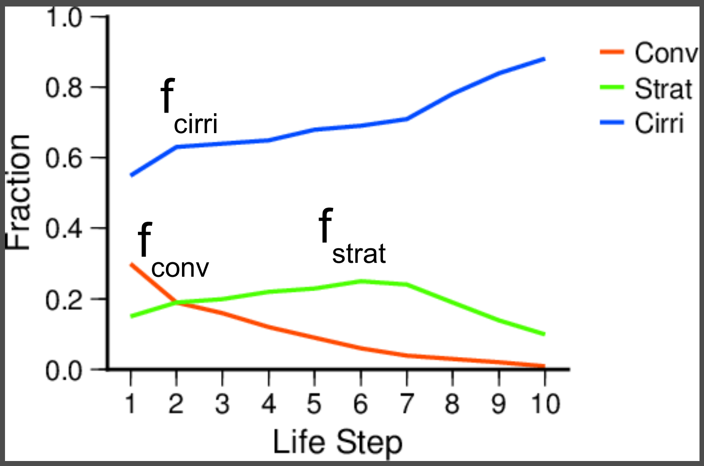
- use of 2A25 convective/stratiform flag within the 235K area
- at least 70 % of 235 K area of the sampled MCS must be in the TRMM-PR swath



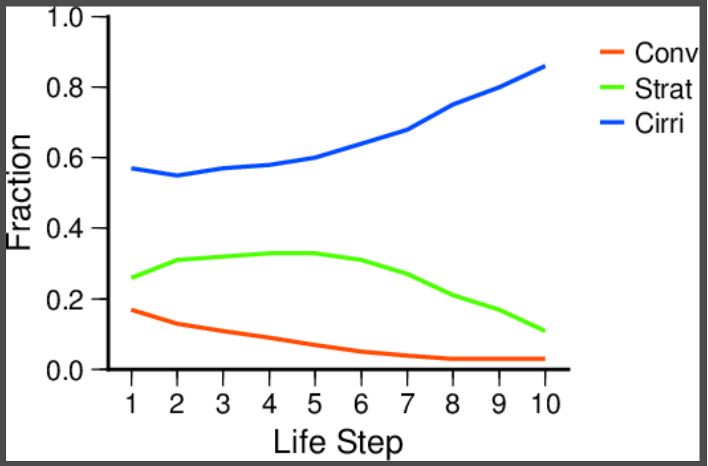
AF



ATL



OIO



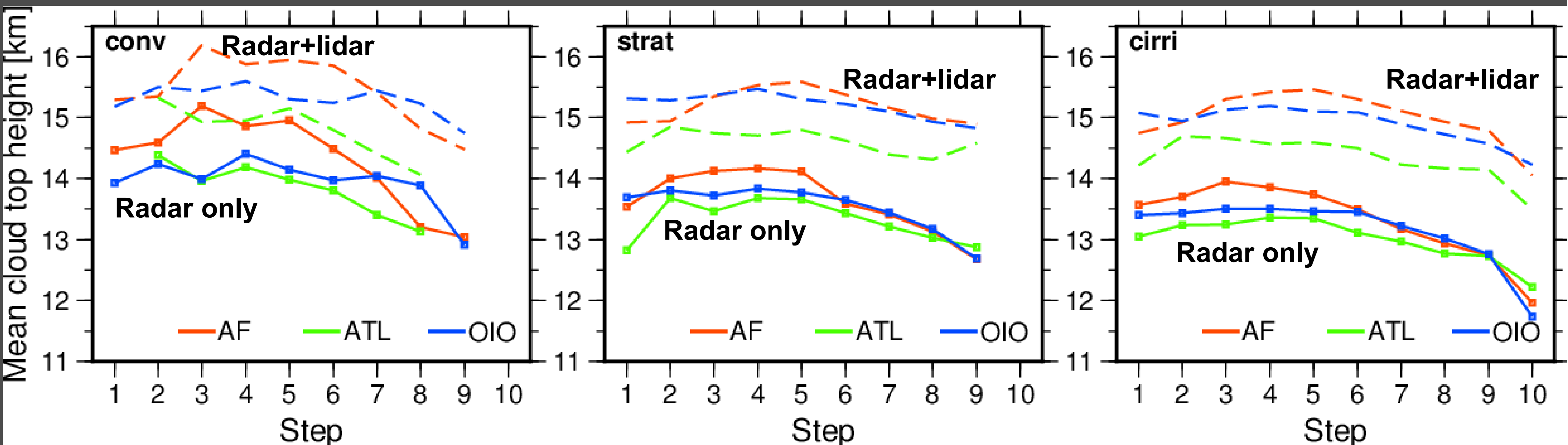
Cirriform region counts for more than half of the MCS area – only grews over the life cycle <=> the precipitating surface fraction ($f_p = f_{conv} + f_{strat}$) is only decreasing.

Convective fraction is only decreasing

Stratiform fraction ~ constant up to 2/3 of the life cycle

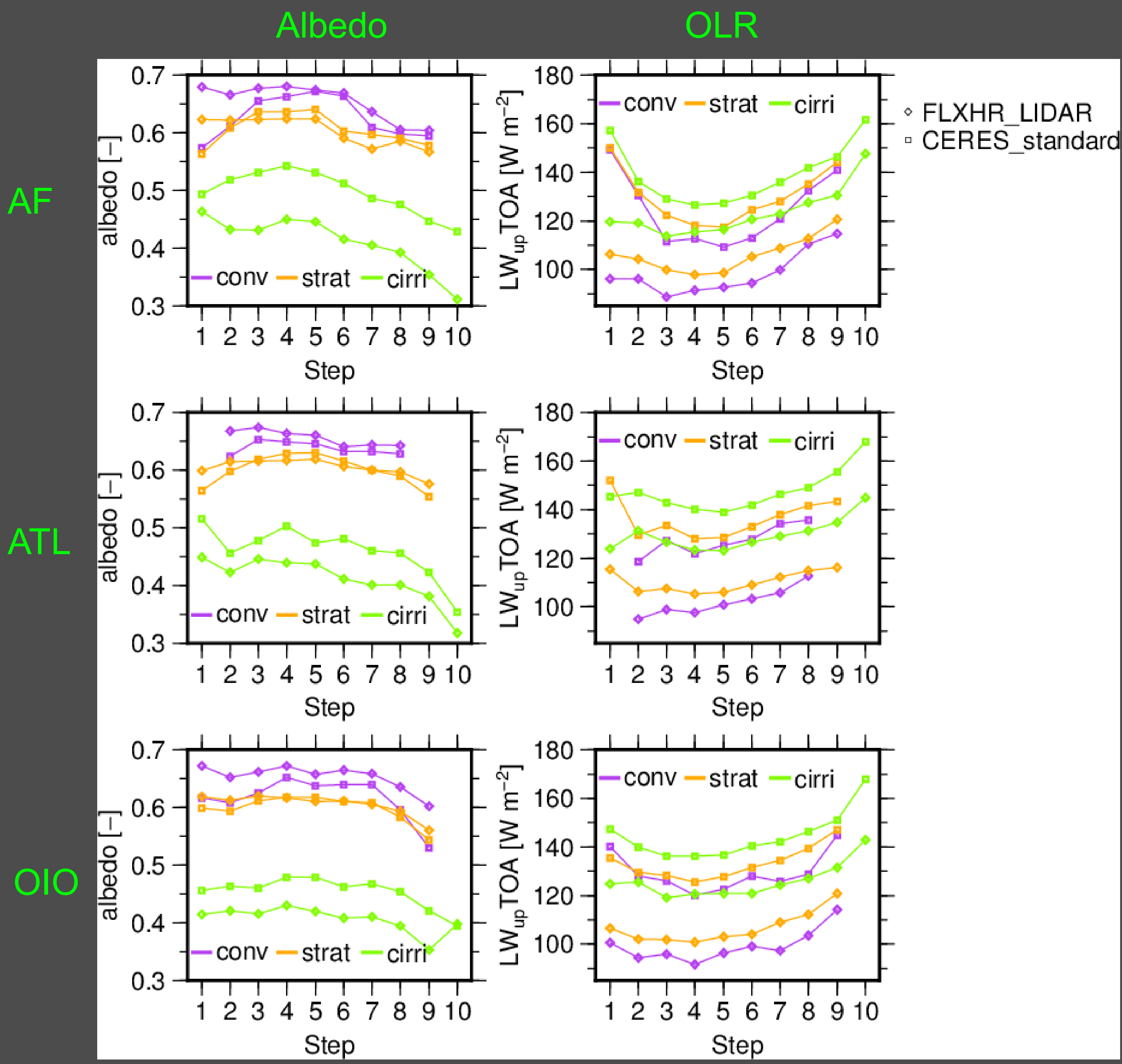
Differences in macrophysical properties :

Cloud top as as observed by CloudSat : ———— by CloudSat + CALIPSO : --------



- Highest cloud top at the beginning of the life cycle for AF MCS (but rapid decrease after step 5) – less pronounced life cycle for other regions
- Decrease in cloud top faster for radar data than for lidar data => deepening of the small particles layer with the life cycle
- It exists a layer of thin particles at the top of the MCS – contribution to albedo (Jensen & DelGenio 2003)
- Radar+lidar cloud top higher for OIO wrt ATL / Radar cloud top very close

Evolution of radiative fluxes @ TOA :



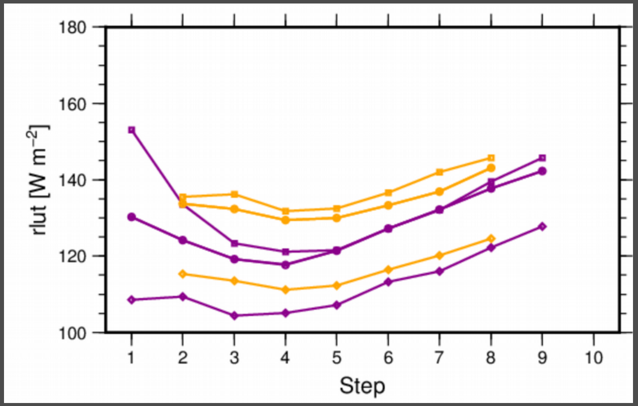
albedo : same order of magnitude (~0.6) for conv and strat different evolution according to geographical area : faster decrease in AF after step 5 (thinning of MCS anvil)

OLR: about 10 W m^{-2} between the 3 sub-regions (larger values for cirri)
AF shows the more marked life cycle with a decrease up to step 4 (amplitude ~ 30 W m^{-2} for AF / < 20 W m^{-2} over ocean)
=> well correlated with radar cloud-top

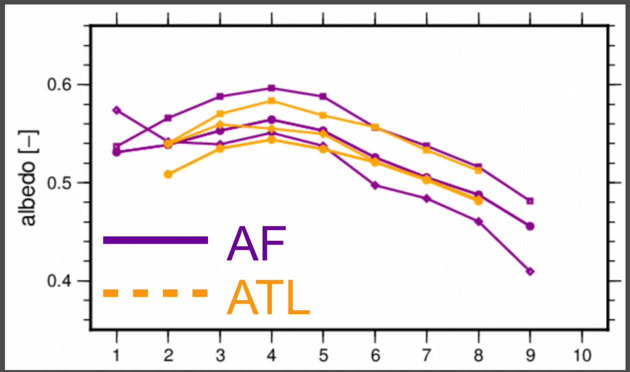
Evolution of the radiative properties at the scale of the MCS :

Assuming a linear recombination of the former composites (parameter Q) weighted by MCS sub-region surface fraction (f) evolution

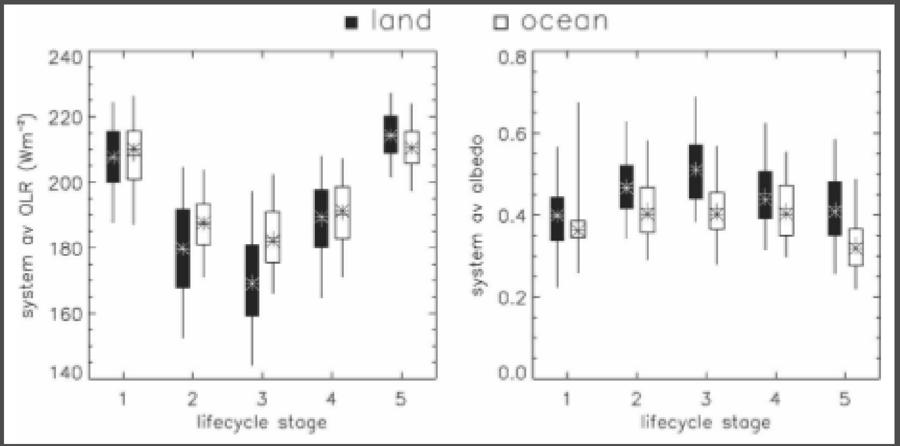
$$\langle Q(i)\rangle = \sum_{j=1}^{3} f_j(i)\, Q_j(i)$$



CERES
FLXHR-LIDAR
MODIS



Can be compared to Futyan and Del Genio (2007) same regions but different IR Tb threshold



- The size of the cirriform region (more than half of the 235K area) makes the system dominated by the radiative properties of this sub-region.
- Smaller/larger values for OLR/albedo compared to F&DG because of the 235K Flatter evolution over ocean for OLR
- No brighter MCSs over continent (product dependant) as in F&DG – can be explained by the fp contribution vrt cirriform

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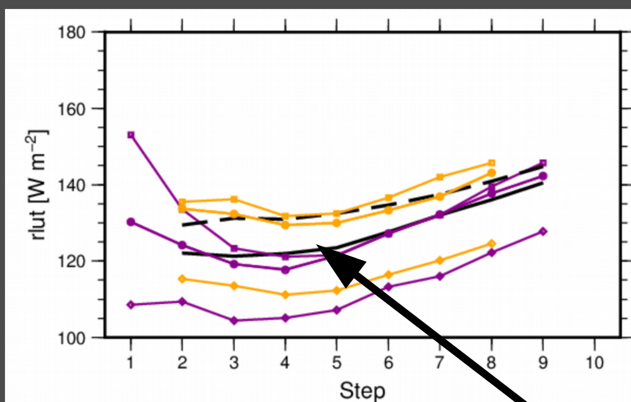

CERES
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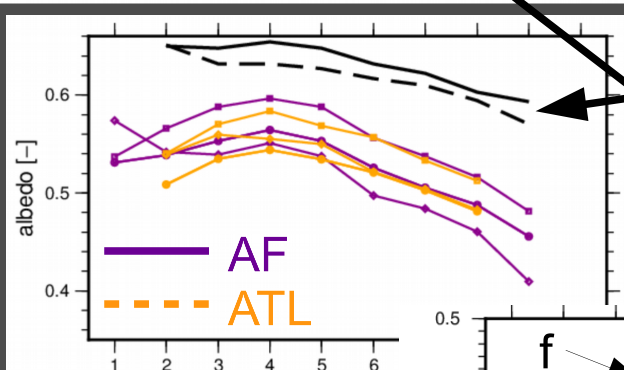
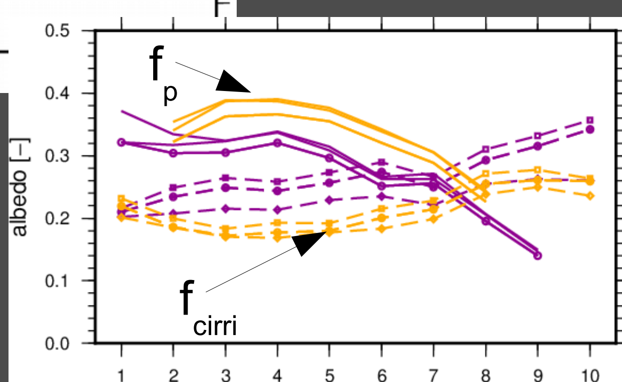


ScaraB
(all time)
Need 1.30



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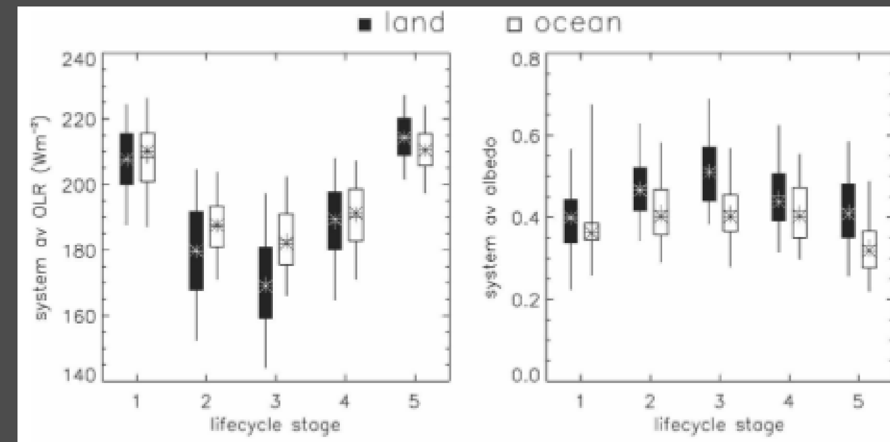

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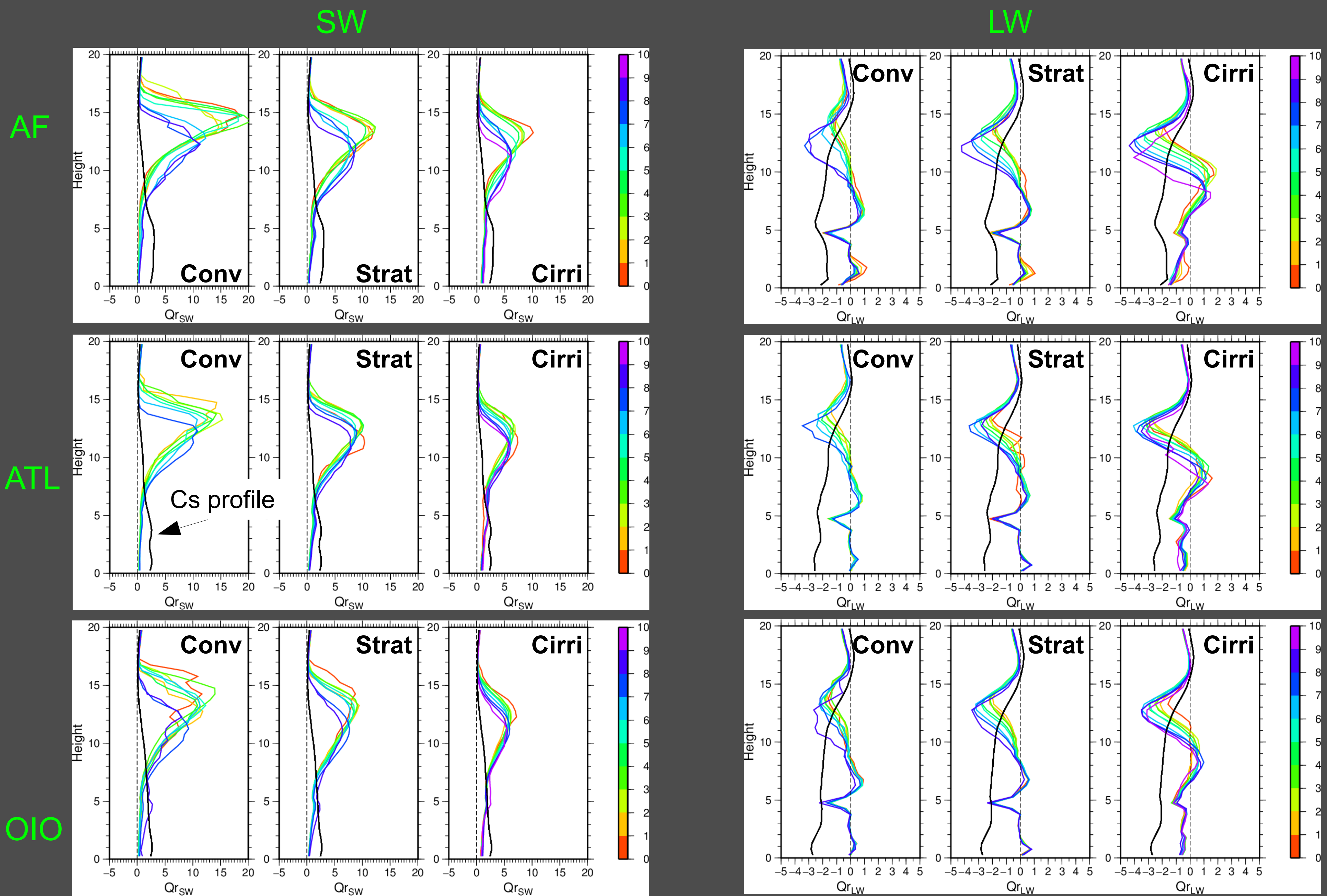
Evolution of the radiative heating profile over life cycle:



SW: strong heating below radar cloud top (forcing > 10 K day^{-1}) with decreased magnitude with life step

LW: cooling near cloud top / heating in the lower part of the anvil => fuel the internal anvil circulation

Summary :

- MCS are the dominant rain producer and a major source of cold cloudiness in the Tropics
- The complementary of several satellite data sets allows to document the contribution of MCS to water and energy cycle in the Tropics.

- More than 80 % of the MCSs have a symmetric life cycle with a maximum extend at the middle of their life cycle.
  - a normalisation procedure is applied

- A composite approach has been implemented in order to document the physical processes over the MCS life cycle (divided in 10 life steps).
  - convective/stratiform/cirriform regions are documented separately
  - this process has been applied to 3 contrasted regions (AF/ATL/OIO)
  - the cirriform region occupies more than half of the system area

- A layer of small hydrometeors is found at the top of the MCS
- Intense vertical motions are found at the beginning of the life cycle for AF
  - deeper high reflectivity value + detrainment up to the cirriform anvil.
  - convection weakens rapidly after half of the life cycle
  - strong correlation in the evolution of albedo and OLR with the reflectivity
  - stronger heating (in the SW) at the beginning of the life cycle
- Oceanic MCS show less pronounced life cycle, the same correlations can be found but with smaller amplitude

More details in Bouniol et al. (JClim, 2016), Roca et al. (in rev. JClim 2016)

Future work :

- Enlarge the statistics (begin/end of Life Cycle)

- Document the variability at the scale of the tropical belt
  3 summer of tracking are available for the whole tropical belt

- More accurate recombination of the contribution of the 3 sub-regions at the scale of the MCS
  - explore the albedo dependency to LT (using ScaraB and/or GERB)
  - in particular for the diurnal cycle of rsdt

- Complement the documentation of radiative heating evolution over the life cycle with the latent heating

- What is the importance of the life cycle for the radiative budget at a regional scale ?